COARSE WOODY DEBRIS CONSIDERATIONS IN SOUTHERN SILVICULTURE[1]

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Abstract—Coarse woody debris (CWD)–standing dead trees, fallen trees, and decomposing large roots serve a number of ecological functions. CWD loadings are dynamic in response to inputs from tree breakage and mortality and to losses from decomposition and fire. Two very different natural processes, gap-phase dynamics and major episodic disturbance, contribute to inputs in addition to forest management activities. Decay and combustion are similar in that, if complete, both yield CO_2 and water. However, neither is usually complete, and the combustion process leaves some rapidly-altered CWD, whereas decay results in the gradual formation of humic substances. Current forest management practices often contribute to low loadings of CWD in southern forests. The FORCAT gap model was used to simulate formation and decomposition of coarse woody debris (CWD) for two forest ecosystems on the Cumberland Plateau in east Tennessee. Model results showed a decrease in CWD loads in early years as logging slash decomposed. After year 32, CWD loads increased rapidly and peaked around year 90. CWD loads in older stands gradually decreased through the remainder of the simulation period. The assumed decomposition rate strongly influenced CWD loading. Model results correspond closely to observed loadings in old-growth stands on the Cumberland Plateau.

INTRODUCTION

Standing dead trees (snags), fallen trees, and decomposing large roots are components of coarse woody debris (CWD) which exert ecological influences on a site for decades or even centuries (Franklin and Waring 1980). CWD functions as seed germination sites, reservoirs of moisture during droughts, sites of nutrient exchange for plant uptake, and as critical habitat components for forest organisms. During later stages of decomposition, it promotes favorable soil structure (Harmon and others 1986, Maser and others 1988). Dead root systems have been neglected as a component of CWD. However, decomposing roots contribute to the heterogeneity of the soil, provide increased infiltration and percolation of soil water, enhance gas diffusion throughout the rooting zone, and provide habitat for soil-dwelling organisms (Lutz and Chandler 1955).

Loadings of CWD are dynamic, i.e., constantly changing in response to inputs from tree breakage and mortality and losses from decomposition and fire. The dynamic nature of CWD is reflected in gradual or episodic changes in mass, density, and volume of standing dead and fallen trees.

Coarse woody debris, in this paper, refers to any dead standing or fallen tree stem (or dead root) at least 7.6 cm in diameter. This minimum diameter was arbitrarily chosen, primarily because it corresponded to a measured size-class in a number of cited studies in the South. For obvious reasons, the dynamics of root biomass of dead trees have received little study.

Little information exists in southern forestry literature regarding levels of CWD found in "natural" or managed forest ecosystems. This paper 1) summarizes our current understanding of CWD dynamics in southern forests, 2) models CWD loading on xeric and mesic sites, and 3) identifies gaps in our knowledge of CWD.

INPUTS OF COARSE WOODY DEBRIS

The flow of above-ground CWD within terrestrial ecosystems is summarized in diagrammatic form (Figure 1), as adapted from Harmon and others (1986). Within terrestrial ecosystems, mortality and breakage of living trees add CWD, while decay and fire remove or transform CWD (Harmon and others 1986, Maser and others 1988). The balance between inputs and losses of CWD within the forest ecosystem represents the standing crop, or loading, of CWD.

Inputs of CWD occur when living trees are killed by fire, wind, lightning, insects, disease, ice storms, competition, or by man. Disturbances may kill scattered individual trees, groups of trees, entire stands, or even devastate entire landscapes and are now widely recognized as a natural part of the ecology of the southern forest (Christensen 1991, Sharitz and

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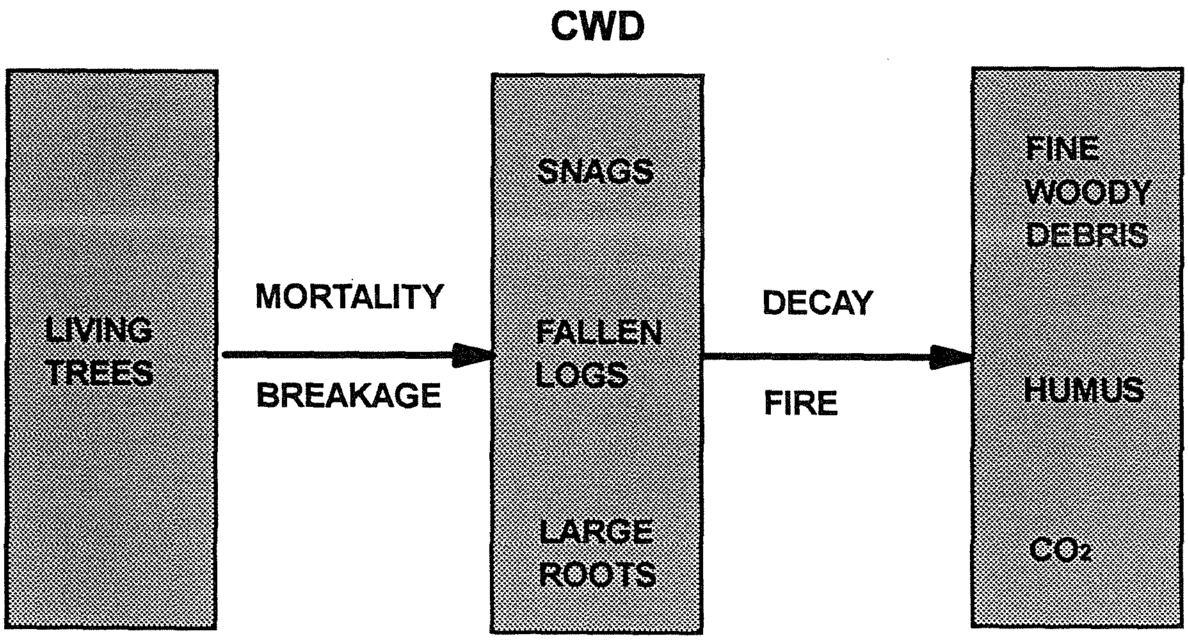

Figure 1. Flow diagram of the dynamics of CWD in terrestrial ecosystems.

others 1992, Skeen and others 1993). Major disturbances contribute large quantities of CWD, which are added to pre-disturbance CWD already accumulated in the stand. For this reason, loadings of CWD are often highest soon after major forest disturbances.

Gradual Inputs of CWD by Gap-Phase Dynamics

CWD inputs in southern forests from gradual gap-phase dynamics, i.e., the occasional death of individual trees or groups of trees within the forest, are not well documented. Large canopy gaps can contribute substantial quantities of CWD. For example, Smith (1991) estimated that canopy gaps created in pitch pine stands by pine beetles in the Southern Appalachians contained 35.6 t/ha of CWD. Loadings from insect damage in more productive forest types could be much higher.

Some information on snag densities (numbers/area) and recruitment rates is available from the wildlife literature. Generalizations from published research include: 1) snags are most common in hardwood stands and least common in pure pine stands (Harlow and Guynn 1983, McComb and others 1986b, Sabin 1991), 2) snags are more frequent in lowlands and riparian zones than on upland sites, and 3) unmanaged private land and national forests generally have higher densities of snags than lands managed intensively for wood production (McComb and others 1986a, 1986b).

The length of time that snags remain standing varies with species and size, although most snags fall within a decade or less in Southern forests (Dickenson and others 1983, McComb and Rumsey 1983, Sabin 1991). However, occasional American chestnut snags are still standing in Southern Appalachian forests 70 years after the chestnut blight. White pine and white oaks are generally longer standing than snags of other pine and oak species (Hassinger and Payne 1988). Large diameter snags stand longer than smaller ones (Bull 1983, Raphael and Morrison 1987).

Snag densities in the relatively young forests of the South vary widely. In the Appalachian deciduous forest, Carey (1983) found snag densities ranging from 11 to 55 snags/ha. Sabin (1991) reported an overall snag density of 28.1 snags/ha in relatively young (20 to 60+ yrs) forest types in the Piedmont and noted that snags were being lost at an average rate of 0.52 snags/ha/yr. Relatively few areas and little acreage in the Southeast support over-mature or old-growth forests where snag recruitment rates and densities are unknown. Such information is needed to serve as baseline data against which forests managed more intensively could be compared.

Major Episodic Disturbances Which Create Heavy Loading of CWD

In contrast to gap-phase disturbances where natural succession proceeds at a relatively gradual rate, large-scale natural disturbances, such as catastrophic wildfires and hurricanes, are episodic in nature and may kill trees over large forest areas. As a result of these natural disturbances and timber harvesting by man, few forest ecosystems in the Southeastern United States succeed to a vegetative climax condition or even develop undisturbed for as long as a century.

Forest fires affect the loading of CWD by simultaneously adding CWD by killing live trees and reducing CWD by consuming dead trees. Fire regimes in the South range from those where fire reoccurs infrequently (on the order of several decades to perhaps a century or more) and fuel loading is heavy to those where fire occurs on almost an annual basis and fuels are light. Sand pine and table mountain pine regenerate after catastrophic stand-replacement fires which function to open serotinous cones, kill hardwood understory competition, and prepare seedbeds (Outcalt and Balmer 1983, Della-Bianca 1990), as well as contribute a large pulse of CWD. At the other extreme, the longleaf pine-wiregrass ecosystem typifies a regime of frequent fire, which prevents the buildup of fuels to levels where high rates of fire-induced tree mortality would be expected. Boyer (1979) reported an annual mortality of only 1 tree/ha in mature longleaf pine stands throughout the longleaf region.

Stand-replacement fires which kill all above-ground biomass obviously make heavy contributions to CWD. The author knows of no studies in the South where CWD inputs have been estimated following stand-replacement fires. However, estimates of above-ground living biomass are available for some forest types and site conditions and provide a rough approximation, when corrected for small branch and foliage components, of potential CWD inputs. About 70-80% of the above-ground biomass of these forest types is above the minimum size class of CWD. For loblolly pine, the most studied of the southern pines, above-ground biomass ranges from about 100 t/ha in thinned 41-year-old plantations on poor sites (Van Lear and others 1983) to approximately 156 t/ha for unthinned 16-year-old plantations on good sites (Wells and Jorgensen 1975). Above-ground biomass of mixed hardwood stands averaged 178 and 175 t/ha at Coweeta Hydrologic Laboratory and Oak Ridge National Laboratory, respectively (Mann and others 1988), similar to the 164 t/ha estimate from forest survey data for fully stocked stands of mature hardwoods in the Southeast (Phillips and Sheffield 1984).

Hurricanes, tornadoes, and other strong winds are common in the southeastern United States and strongly influence CWD dynamics. These strong winds create in a matter of hours loadings of CWD that would never be achieved during centuries of gap-phase natural succession (Hook and others 1991). For example, Myers and others (1993) measured loadings, after limited salvage, of almost 90 t/ha of downed woody material and 16 t/ha of snags in mature, uneven aged pine stands two years after Hurricane Hugo. Strong winds either snap stems of well-anchored species or uproot shallow-rooted species. Although catastrophic winds (probably category V force winds) will destroy any stand, such winds normally occur over only a relatively small portion of the area affected by most hurricanes.

Forest damage from hurricanes and tornados has increased in recent decades due to the regrowth of mature forests following the extensive harvest of old-growth forests that occurred between 1885-1930 (Hooper and McAdie 1993). In addition to stand age, site (Croker 1958, Foster 1988), community type (Duever and McCollum 1993, Sharitz and others 1993), species (Touliatos and Roth 1971, Hook and others 1991, Gresham and others 1991, Sharitz and others 1993) and tree morphology (Gratkowski 1956, Nix and Ruckelshaus 1990) markedly influence the damage (and CWD loadings) to forests by strong winds.

Other environmental factors, e.g., insect and disease outbreaks, ice storms, and mass movement of soils, can dramatically increase loadings of CWD. Some native insects, the Southern pine beetle for example, periodically reach epidemic proportions and kill whole stands of various pine species across large portions of the landscape. Introduced insects like the gypsy moth continue to expand their range southward and devastate hardwood stands over extensive areas. Certain diseases, for example, fusiform rust, have become more prevalent in recent decades. Ice storms periodically wreak havoc on forests in some portions of the South, e.g., in the Sandhills region.

The quantity of CWD contributed to sites by all these factors is a function of the proportion of the stand killed (and consumed in the case of fire) by these agents and the proportion of the trees above the minimum CWD size class. Contributions range from the mortality of scattered individual trees killed in non-episodic events to the mass deaths of trees on thousands of hectares during major episodic events, during which the loading of CWD across the landscape is increased dramatically. Information on CWD inputs from all types of catastrophic events is needed in order to fully evaluate the environmental effects of these disturbances.

LOSSES OF CWD

Within terrestrial ecosystems, CWD is lost through decay and fire. Decay and combustion by fire are similar processes in some respects, but also have important differences. The relative importance of each process varies by site--decay dominates on mesic sites, while fire is more important on xeric sites (unless fire-suppression efforts are effective). Although its natural role as a major ecological factor has often been overlooked by ecologists and land managers, fire has been a dominant factor shaping the structure and composition of southern forest ecosystems for millennia.

Decay

Decay of CWD is initiated by an invasion of white, brown, and soft rot fungi, causing a loss of density (Kaarik 1974). Insects are known to be important inoculators of these decay microbes (Abbott and Crossley 1982). Toole (1965) described the deterioration of unlopped hardwood logging slash in Mississippi and found that, for most of the species studied, small branches had disintegrated after 6 years and only a small portion (<15%) of the large branches and bole had not settled on the ground. Twigs and small branches decayed most readily, followed by the larger sapwood and finally the heartwood. Decay may be retarded when the bark sloughs off early, allowing the surface of the sapwood to dry quickly and become casehardened. Smith (1991) documented changes in decomposer communities of pitch pine CWD during decomposition. During early stages of decomposition, bark beetles and blue-stain fungi dominated, although neither had much effect on decomposition, i.e., wood density was not markedly reduced. White rots, brown rots, ants, and termites dominated later stages of decomposition. As the wood structure is broken down, fragmentation becomes a major mechanism of decay.

Fragmentation of CWD refers to a reduction of volume via physical and biological forces during the decay process (Harmon and others 1986, Maser and others 1988). Fragmentation is normally preceeded by a lag period in which both density and mass of fresh CWD decrease, but volume remains constant. Snags fragment when portions of the standing dead tree or the entire tree break and fall to the ground. Biological fragmentation of snags and fallen logs is caused by both plants and animals. Invertebrates utilize the dead wood as a food source, creating galleries which serve as avenues for microbial colonization and further decay. Bears, birds, and other animals shred the rotting wood while foraging for insects. Plants roots grow into fallen trees after initial stages of decay have been completed and further fragment the partially decomposed materials. During the entire decay process, the physical forces of water and gravity relentlessly transport fragmented materials from snags and fallen logs to the forest floor, where they undergo further decomposition and are ultimately converted to $_{\text{CO.}}$ or decay-resistant humus. The final products of decay of CWD are fine woody debris, humus, and $_{\text{CO.}}$ (Maser and others 1979, Harmon and others 1986, Spies and Cline 1988).

Although perhaps not as good an index of decay as volume diminution, changes in wood density have frequently been used to measure initial stages of physical decay. Following clearcuttting of a mixed hardwood stand in the Southern Appalachians of North Carolina, wood-density decay coefficients varied widely, ranging from 0.18/yr for species such as dogwood and persimmon to 0.03/yr for decay-resistant species like black locust and American chestnut (Mattson and others 1987). Little information is available regarding decay of pine CWD in the South. Barber and Van Lear (1984) calculated a wood-density decay coefficient of 0.075/yr for large loblolly pine slash (excluding bark) following clearcutting in the South Carolina Piedmont, while Smith (1991) found a decay constant of 0.048/yr for pitch pine CWD in the Southern Appalachians.

In addition to species differences, other factors affect the rate of decay of CWD (Barber and Van Lear 1984, Mattson and others 1987). Aspect of the site is important--CWD decays faster on north and northeastern aspects, probably due to the generally greater availability of soil moisture. Relative position of the fallen tree affects decay rates--CWD in contact with the ground decays faster than aerially suspended CWD. Large woody debris decays slower than small woody debris. In streams, saturated CWD decays at extremely slow rates. Decomposition rates in the Southeast are generally higher than those reported for other regions, presumably because temperature and moisture conditions are more favorable for microbes and invertebrates involved in the decay process.

The chemical nature of CWD changes during decomposition. Workers in the Pacific Northwest (Sollins and others 1980, Graham and Cromack 1982) and elsewhere have noted that the C/N ratio of CWD decreases and the concentration of lignin increases as decay progresses. Concentrations of nitrogen and phosphorus increases in large logging slash following harvest of loblolly pine (Barber and Van Lear 1984) an in pitch pine CWD following pine beetle attack (Smith 1991). However, after initially being a sink for nutrients CWD later becomes a source when fragmentation dominates the decay process.

Long-term studies are underway which will better document decay rates of CWD. However, more information is needed concerning decay rates of different species under different site conditions and management regimes. What is the best method for measuring decay? Sampling wood density in various states of decay is frequently used, but the method becomes biased during mid to late stages of decay when only the most resistant pieces of wood remain. Adjustment of decay chronosequences for past fragmentation is necessary, but often difficult, if mass losses are to be estimated correctly (Harmon, persone communication[1]). When does decaying wood becom a source, rather than a sink for nutrients? What types

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of decay models best describe the decay process? These and many other questions reflect gaps in our knowledge of the decay process.

Fire

Fire and decay are similar processes in that both are essentially oxidation reactions and that, if both went to completion, the final products would be $_{CO}$ and water (Brown and Davis 1973). However, fire is the rapid oxidation, or combustion, of fuels, while decay is a much more gradual oxidation of organic materials. In neither process is oxidation generally complete. In forest fires, complete combustion is obviously uncommon, as evidenced by dead snags and downed trees on burned sites. Decay is also generally incomplete, as evidenced by the presence of residual CWD and the formation of humus.

Some of the effects of fire on CWD are similar to those of decay, i.e., fire promotes fragmentation of large pieces of wood and bark into smaller pieces and release of CO. and other gases into the atmosphere. However, the two processes obviously differ in the speed of their reactions and in the type of substrate produced (charred vs. uncharred). Also important is the fact that the decay process generally tends to mesify microsites because of incorporation of humified products into the soil, while fire tends to xerify microsites, at least in the short run, by oxidizing humus from the forest floor and exposing the soil surface to greater insolation.

There are many deficiencies in our knowledge of the role of fire in CWD losses. What is the effect of charring on decay? Under what conditions can fire be used which minimize CWD loss? Is fire compatible with management for snags? What burning regimes are appropriate to achieve and maintain desired loadings of CWD? This last deficiency assumes that we eventually will have some concept of what desired loadings are. Southern forests evolved in regimes of more or less frequent fire. How this major environmental factor influenced CWD loadings on a landscape scale represents a major gap in our understanding of CWD dynamics.

LOADINGS OF CWD IN SOUTHERN FOREST ECOSYSTEMS

There is relatively little data in the South concerning loadings of CWD following major episodic disturbances or through various stages of succession. Studies are needed to characterize more thoroughly loadings of CWD in old-growth forests. How do loadings vary in response to different fire regimes? Are there some forest types where CWD loadings are low because of rapid decay rates or because fire is a frequent visitor? How can management be modified to enhance CWD loadings on both stand and landscape scales? These types of questions must be answered so that managers might have guidelines relative to loadings of CWD in managed stands versus those in stands which have not been manipulated. As research further demonstrates the ecological significance of CWD in Southern forests, current management strategies may need to be altered to achieve certain levels of CWD.

This lack of information prompted the simulation study described in this paper. A previously-developed model of forest succession was used to simulate stand dynamics and CWD loading was predicted from tree mortality. The objectives of this exercise were to provide basic information on long-term CWD dynamics in southeastern ecosystems and to identify information gaps.

The selected model was FORCAT (FORests of the CAToosa Wildlife Management Area), which was developed for mixed-species forests in East Tennessee (Waldrop and others 1986). FORCAT was selected because it is one of only a few existing models capable of simulating long-term stand dynamics for managed, mixed-species stands (Waldrop and others 1989). It is a member of a family of models based on the widely-used FORET gap model (Shugart and West 1977). Gap models are a special case of single-tree models and have demonstrated adaptability to simulate forest succession over a wide range of forest types (Shugart 1984).

The FORCAT model was developed through numerous modifications to FORET, making it more specific to managed sites on the Cumberland Plateau (Waldrop and others 1986). The model simulates stand dynamics on a 1/5-acre plot using 30 hardwood and 3 pine species commonly found in the region. Simulation begins with a mature stand which is immediately clearcut. After clearcutting, sprouts and seedlings are stochastically added to simulated plots. Diameter and height growth are calculated each year for each tree as a function of site, species, competition, and environmental stress. Trees are killed stochastically each year based on age, species, and current growth rates.

Few changes to FORCAT were required to predict CWD loading. During any simulated year, if a tree died it was then considered CWD and its biomass was estimated. Biomass was estimated for both stems and crowns using regression equations given by Clark and others (1986). The total biomass of CWD on a plot was calculated for each year and reduced by a constant rate to allow for decomposition. Decomposition rates of 6% and 8% (Harmon 1982) were used to examine the differences these rates caused in CWD accumulation.

Stand dynamics and CWD accumulation were simulated for two site types (xeric and mesic) to give insight into the effect of site productivity on CWD accumulation. The xeric site was south facing, dominated by upland oaks, and had a site index of 60 feet. The mesic site was north facing, dominated by yellow-poplar, and had a site index of 100 feet. Simulations began with mature stands, which were immediately clearcut. No artificial regeneration or site preparation was allowed. A simulation period of 200 years after clearcutting was used for each of 100 simulated 1/5-acre plots. Details of model development were given by (Waldrop and others 1986). Modeling CWD dynamics with FORCAT and the limitations of this approach were discussed in greater detail by Waldrop (1995).

The patterns of CWD accumulation predicted by FORCAT (Figure 2) for xeric and mesic sites (using a 6 percent decomposition rate for both sites) were similar to the curve proposed by Spies and Cline (1988). These patterns resembled a bell-shaped curve that peaked during the first half of their respective periods (100 years for simulated xeric and mesic sites, 450 years for measured Douglas-fir stands). Later, CWD in each system gradually decreased until a point, late in succession, where an equilibrium between inputs and decomposition may have been reached.

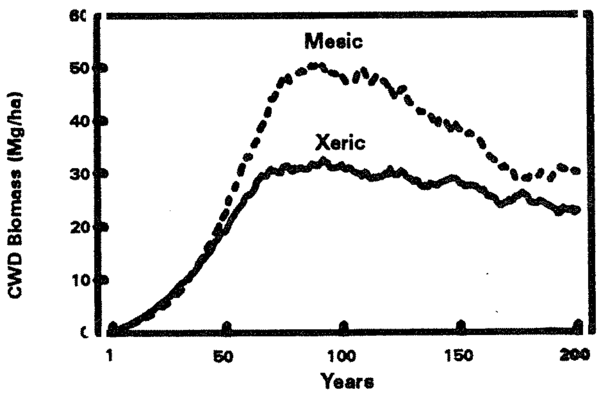

Figure 2.--Accumulation of coarse woody debris for xeric and mesic sites as predicted by FORCAT (6 percent decomposition rate for both sites).

CWD accumulation on both simulated sites remained low for 30 to 40 years as trees grew to the minimum size for CWD (10 cm), even though there was significant mortality during this period. Between years 30 and 75 there was a rapid increase in CWD for both simulated sites. FORCAT predicted decreases in stand basal area during this period as crown closure occurred and a few large trees began to die. On the xeric site, for example, predicted stand basal area decreased from 84 ft^2 at year 50 to 69 ft^2 at year 100.

The period of rapid CWD accumulation on the xeric site lasted until the stand was about 70 years old, when CWD was 13.6 tons/ac. CWD continued to accumulate, but at a slower rate, to a maximum of 14.4 tons/ac at year 91. For the remainder of the 200-year simulation period, decomposition slightly exceeded inputs and CWD loads gradually decreased.

Tree growth on the simulated mesic site exceeded that on the xeric site, producing a more rapid rate of CWD accumulation. On this site, CWD accumulated rapidly from years 30 through 75, reaching a total of 22.0 tons/ac. Maximum CWD loading during the simulation period was 22.9 tons/ac in year 89. Between years 90 and 200, CWD loading decreased much more rapidly than on the xeric site. Species on the mesic site were longer lived than those on the xeric site and the trees continued to grow. Mortality was higher on the xeric site during this period due to moisture stress. Therefore, CWD inputs were less on the mesic site than the xeric site.

An important component of CWD dynamics in managed stands is logging debris. This debris provides regenerating stands with a structure that can be important habitat for small mammals (Evans and others 1991, Loeb 1994) as well as a source of nutrients (Mattson and others 1987). Logging slash was added to model projections of CWD inputs immediately after simulated clearcutting. Total CWD loading at that time was assumed to equal the biomass of crowns from harvested trees.

The estimated CWD load immediately after clearcutting was 21.8 tons/ac on the xeric site and 30.7 tons/ac on the mesic site (Figure 3). On both sites, these levels were higher than at any other time during the 200-year simulation period. Logging debris decomposes rapidly in clearcuts but it provides some CWD during a period when there is little input. FORCAT simulations showed that decomposition exceeded inputs through year 32. At that time CWD totaled 7.5 tons/ac on the xeric site and 8.1 tons/ac on the mesic site (assuming a uniform decomposition rate of 6 percent). By year 32, all logging slash had decomposed, and thereafter, these curves were identical to those without logging slash.

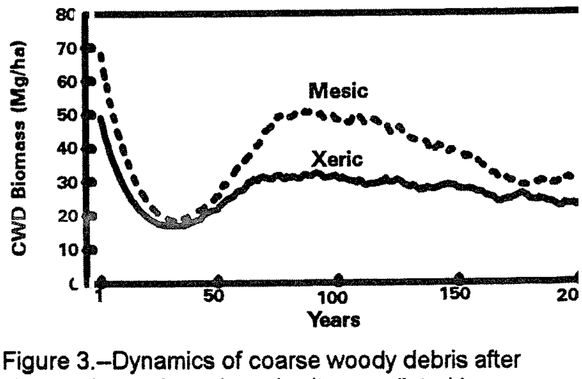

Figure 3.--Dynamics of coarse woody debris after clearcutting xeric and mesic sites predicted by FORCAT (using a 6 percent decomposition rate for both sites).

An assumption used until now is that decomposition rates were uniform across site types. The work of Abbott and Crossley (1982) indicates that decomposition rates are higher on moist sites. By assuming a decomposition rate of 8 percent on the mesic site and 6 percent on the xeric site, the difference in simulated CWD loads between sites was greatly reduced (Figure 4). Even though CWD loading was much higher on the mesic site in year 1, it decomposed to a smaller amount than the xeric site by year 32 (5.5 vs. 7.5 tons/ac). By year 75, CWD was again greater on the mesic site. Beyond that point, however, the lines converged. **During the last 50 years of the simulation, CWD loads on the two simulated sites were nearly identical.**

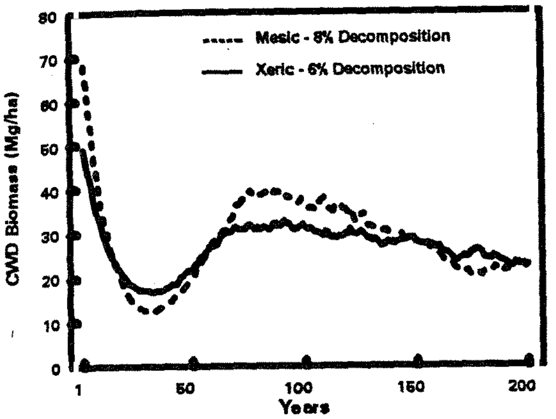

Figure 4.--FORCAT projections of coarse woody debris loads by site type and decomposition rate.

This comparison illustrates the observation of Abbott and Crossley (1982) that differences in decomposition rates between sites can be more important than differences in sizes of CWD. Even though the mesic site produced far more CWD biomass than the xeric site, the relatively small difference in decomposition rates (8 vs. 6 percent) produced similar CWD loading throughout the 200-year simulation.

Muller and Liu (1991) suggested that CWD loading was a function of regional temperature patterns. Their measurements on dry sites correlated well with published estimates from warm temperate zone deciduous forests. Likewise, their CWD measurements on moist sites correlated well with published estimates from cool forests. Muller and Liu (1991) observed higher CWD loads on cool (moist) sites than on warm (dry) sites, suggesting that decomposition rates were not higher on moist sites or that higher productivity on moist sites compensated for higher decomposition rates. Broad-scale relationships, such as this, are oversimplified because CWD decomposition on any given site is controlled by a combination of moisture, temperature, soil fertility, species, size, and any number of other factors.

CONCLUSIONS

The ecological importance of CWD is only recently being appreciated by foresters and other land managers in the South. Based on the documented importance of CWD in the Pacific Northwest and other areas, as well as on the information presented at this workshop, it would be prudent for land managers in the Southeast to recognize CWD as an important structural and functional component of forest ecosystems, rather than as a hindrance which must be removed--even if at a high cost.

Simulation results show general trends of CWD accumulation over seral stages for two southeastern forest ecosystems. This study shows the importance of leaving CWD after harvesting and it emphasizes that differences in decomposition rates, possibly due to differences in site productivity, can significantly affect CWD loading. Due to a number of limitations, however, model projections should not be considered accurate predictions of CWD loading at any given age.

A major limitation of this study was the lack of information on inputs and decomposition rates for different tree species, sizes of CWD, and types of sites. Other knowledge gaps were discussed by Van Lear (1995) including the relationship of CWD inputs to natural and anthropogenic disturbance. Some of this missing information could be supplied by additional research and a broader modeling effort. For example, CWD dynamics after natural disturbances such as tornados or ice storms could be predicted by gap models if the return frequency of those disturbances was known. Also, CWD inputs from management activities such as thinnings or selection harvests could be predicted. This effort would allow managers to use model projections to help determine how to alter the level or timing of their activities to better meet their goals for CWD.

Managing for CWD will certainly not be a primary objective on all forest lands in the South. The South is obviously an important timber producer for the nation and the world, and many of the South's forests will be managed primarily for timber. However, managers should be aware of the important functions of CWD and use this information as they strive to achieve the balance between commodity production and environmental values across the landscape.

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Eighty-eight papers and two abstracts address a range of issues affecting southern forests. Papers are grouped in several categories including a general session, ecosystem management, vegetation management, pest management, natural disturbance, biometrics, economics, site productivity, site impacts, ecophysiology, genetics, regeneration, silvicultural systems, stand development, and intermediate management. Fourteen papers, on varying topics, are presented from a poster session.